Making sense of modern wireless hearing aid technologies

BY JASON GALSTER

Before diving into the topic of the technology behind wireless hearing aids, it is important to define two key concepts. The first is wireless frequency. This is the frequency at which a wireless signal is transmitted. In the context of hearing aids, a low-frequency wireless signal would be in the range of 10MHz and a high-frequency wireless signal would be in the range of 2.4GHz. The wireless frequency does not reflect the information that is sent; it is simply a frequency around which information is transmitted. The second concept is a wireless protocol. A protocol is similar to a language; for instance two wireless protocols can be sent at the same transmission frequency without conflict. An example of this would be the comparison of your wireless computer mouse and your mobile phone. It is likely that both the mouse and mobile phone use a 2.4GHz signal for communication, but the mobile phone uses the Bluetooth protocol to send information, and the wireless computer mouse uses a different, lower-power protocol, also transmitted at 2.4GHz, to communicate with your computer. Keeping pace with today's wireless hearing aid technology is challenging. A quick scan of the landscape will reveal no less than six different hearing aid companies each developing wireless hearing aids. The products of these companies can be grouped as transmitting wireless signals around three different frequencies; however, each company uses a proprietary wireless protocol and several use two different protocols.

Less than a decade ago, things were much simpler. Hearing aids had basic components capable of wireless audio transmission. These components, known to consumers and hearing professionals as telecoils, are a magnetic rod wrapped in copper wire. This coil of copper surrounding the magnetic core detects a controlled magnetic field, catching electromagnetic signals modulated at audio frequency ranges and transforming them to electrical signals by the telecoil.

For many people with hearing loss, the telecoil is an indispensable tool for accessing audio from the magnetic output of telephones or magnetic induction fields that are installed for public audio broadcast (e.g. a classroom lecture or show at the theatre). These same individuals would be quick to point out the disadvantages of telecoil use. Hearing aid orientation plays a large role in the successful use of a telecoil, and many savvy hearing aid wearers have developed compensatory strategies that help to address this particular challenge. Beyond orientation, the quality of induction loop installation or the magnetic field strength of a telephone receiver will greatly affect audio signal quality and consistency.

Regardless of signal quality or accessibility, one fundamental ability is absent from standard implementation of a telecoil: the ability to transmit complex data for ear-specific signal processing purposes. The introduction of modern wireless technologies has overcome that limitation and opened doors for novel technology development.

The first in the modern generation of wireless hearing aids used near-field magnetic induction (NFMI). These hearing aids use a small magnet wrapped in a copper coil as the antenna that transmits and receives the wireless signal. The antenna connects to an integrated circuit called a radio; this radio is the brain of the entire wireless system, controlling the transmission and reception of information. Compared to the other wireless hearing aid protocols, NFMI is a low-frequency wireless signal that, depending on the manufacturer, ranges from 4MHz to 14MHz. This remains the most common wireless strategy used in hearing aids today.

For the developers of hearing aid technology, it is reasonable to assume that NFMI was selected for a number of beneficial reasons. Those reasons include a magnetic antenna that is small in size, easing the packaging of the wireless hardware into the hearing aid; a low-frequency signal that transmits easily between ears to allow ear-to-ear signal processing at high data rates; magnetic signal transmission that is relatively low in power consumption; and low signal strength, limiting transmission distance from the hearing aid, thus easing management of wireless interference.

Of course, with advantages also come disadvantages. In the case of NFMI, the low-frequency magnetic signal has a short transmission distance, requiring a neck-worn relay device to translate the signal from a magnetic protocol to a high-frequency wireless protocol that is capable of longer distance signal transmission, most commonly the standardised Bluetooth protocol.

The next highest wireless frequency used in hearing aids is 900MHz. Antennas for 900MHz transmission are small, printed strips of copper that wrap the inside of each hearing aid. At higher frequencies such as 900MHz, less signal strength is lost when transmitting over a distance. As a result, the transmission from hearing aid to a remote device is several metres, freeing the hearing aid wearer from the need of a neck-worn relay device. The 900MHz transmission frequency also falls in a sufficiently low-frequency spectrum that high-data rate ear-to-ear signal processing remains a possibility. A disadvantage to the use of a 900MHz wireless protocol is that there are some limitations to distribution in countries where the same frequency band is allocated specifically for medical device use. The design of a 900MHz antenna is challenging, as it must be specially designed to work efficiently in a hearing aid.

The highest of the three wireless frequencies is 2.4GHz. This is the same frequency band that is used for the standardised Bluetooth wireless protocol. It should be noted, however, that there are many wireless technologies that are not Bluetooth, but also transmit at 2.4GHz (e.g. routers used for wireless Internet connections, remote video game controllers, remote computer mice, and keyboards). Though differences exist, the 2.4GHz antennas are approximately similar to the printed copper antennas used at 900MHz. Wireless signal transmission in the 2.4GHz frequency band allows for long-distance signal transmission, over which data and audio can be transmitted over several metres directly to a hearing aid without the need for a neck-worn relay. The high-frequency nature of wireless signals transmitted at 2.4GHz inherently means that there is increased wireless signal absorption by the body. For this reason ear-to-ear communication is a more challenging prospect, limiting the data exchange rates and how deeply in the canal the hearing aid antenna can be placed. One benefit of the 2.4GHz band is the fact that devices transmitting in this frequency range can be distributed globally.

It should be apparent that none of the three described wireless strategies and their transmission protocols are the standardised Bluetooth protocol. The reason for this is rather simple and relates to power consumption: the hardware required for Bluetooth transmission can fit inside a hearing aid, but the power requirements would limit the battery life of a hearing aid's zinc air battery to several hours.

The current Bluetooth 4.0 standard includes a variant of the Bluetooth protocol that allows for low power consumption when sharing data wirelessly. This low-power protocol periodically shares small amounts of data, improving power efficiency when compared to similar tasks using the original Bluetooth protocol. A limitation to this low-power version of Bluetooth is an inability to transmit wireless audio.

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Working in collaboration with leading hearing aid companies, Apple has created a wireless protocol for hearing aids that combines low-power Bluetooth with the ability to transmit audio. The result is Made for iPhone hearing aids that use a 2.4GHz signal to communicate directly with Apple products, removing the need for a neck-worn relay. Made for iPhone hearing aids allow patients to benefit from stereo audio streaming and data sharing directly from their iPhones. These hearing aids have access to audio and data from the Internet, movement of the phone in space, as well as position information from GPS satellites, all supported by the processing capabilities of the iPhone. Some examples of available benefits can be found in Starkey Hearing Technologies' Halo hearing aids. These include a feature that turns the iPhone into a wireless remote microphone that can be placed closely to a talker of interest, improving the quality of their speech. A second optional feature uses GPS location tracking to allow for user-defined location-specific hearing aid settings that automatically activate when walking into previously 'tagged' locations.

The development of wireless technologies shows no sign of slowing; there will remain a wide range of wireless strategies in hearing aids and new ones will be introduced. Each new technology and feature will offer different opportunities for patients with hearing loss to experience new benefits. This is an exciting time to build a strong foundation of knowledge around wireless hearing aid technology. That foundation will offer strong support for the advances to come.

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Declaration of Competing Interests
JG is a salaried employee of Starkey Hearing Technologies; a company specialising in the development and manufacture of hearing aids.